Numerical Weather Prediction

Assimilation of MOPS moisture data from the Nimrod nowcasting system into the UK Mesoscale Model

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by

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Abstract

A trial is reported of a new version of the Moisture Observation Pre-processing System (MOPS) run within the Nimrod nowcasting system and providing data for assimilation by the UK Mesoscale Model. Subjective assessment of 64 precipitation forecasts favoured the Nimrod version of MOPS on 30% of occasions, with the operational version preferred in 9% of forecasts. Objective verification of cloud cover against surface reports showed the Nimrod version performing slightly better over the first 9 hours, with a null impact overall later in the forecast. Impact on screen temperature and 10-metre wind fields was very small; there was a slight degradation in screen level humidity errors. The Nimrod version of MOPS was implemented operationally on 4th June 1996.

1. Nimrod version of MOPS

The Moisture Observation Pre-processing System (MOPS) has provided valuable cloud data for assimilation by the UK Mesoscale Model (MES) for several years. The components of the MOPS cloud analysis and its impact on MES forecasts are described by Macpherson et al. (1996). Recently, the MOPS precipitation rate analysis was incorporated within the MES assimilation scheme by a 'latent heat nudging' technique, with benefit for short period forecasts of the precipitation distribution (Jones and Macpherson, 1996). This report describes experience with a new version of MOPS run within the Nimrod nowcasting system (Golding, 1995).

The main motivation for moving to the Nimrod version of MOPS is to take advantage of developments in satellite image processing which can benefit both nowcasting and Numerical Weather Prediction (NWP) products. The Nimrod version exploits visible imagery (Jackson, 1995) as well as infrared imagery in generating its basic cloud mask, while the operational version (ie operational at the time of the trial discussed here) only had access to infrared data. The kind of case where we anticipate benefit from visible imagery is where, for example, large areas of the North Sea are covered in low cloud with a cloud top temperature close to the sea temperature. Such cloud looks 'invisible' in the infrared and the outcome of using only infrared data can be that spurious clear areas are inserted in the model analysis.

A second distinctive feature of the Nimrod version is that it traces the use of observations throughout the generation of its 3-dimensional cloud analysis. The lowest layer altered by satellite cloud top data, the highest altered by surface reports and all layers altered to fit cloud cover data, are monitored and used to set missing data indicators where the final analysis does not differ from the background cloud field. This is an attempt to avoid the assimilation of model background information which takes place in the operational version.

The Nimrod background field is a weighted combination of persistence and an 'extrapolation' forecast from the previous hour's cloud analysis, along with a model background field, while the background field for the operational MOPS comes only from the model. The model data supplied to Nimrod may have a verifying time of t+3, 6 or 9, while the operational MOPS always uses a t+3 forecast from the previous 3-hourly model analysis. The variation in 'age' of the model data for Nimrod is a consequence of its generation in one of four main MES forecasts run with data times 6 hours apart.

There are several differences of detail in the way the Nimrod version uses cloud information and derives the final 3-dimensional cloud analysis. As well as rejecting satellite cloud top heights where the background field indicates high cloud, these data are also rejected if there is large variation among neighbouring satellite pixels. More than 50% of pixels in a MES grid-square must have cloud top in the same analysis layer for the information to be used. Unlike the operational version, the Nimrod version does not use a cloud base analysis to constrain the layer analyses of cloud fraction, since in areas of rapid change of cloud base, this has been found to remove observed low cloud layers. The layer analyses are carried out on horizontal levels at fixed heights above sea level so as to correctly represent the intersection of low cloud layers with

topography. The operational MOPS uses vertical levels at fixed heights above model orography.

The precipitation rate analysis from the Nimrod version is an average of the basic 5km radar analysis to 15km resolution, followed by interpolation to the MES grid. The operational MOPS precipitation analysis is a blend of the same radar information with interpreted present weather reports, but with additional smoothing of the analysis to an effective scale of 2-3 model gridlengths (35-50km).

2. The trial

The trial was conducted in parallel with operational runs, in real time, and was run in two phases - the first began on 29/03/96 and lasted 6 days, the second began on 10th April and lasted 10 days. A parallel trial, rather than case-study, approach was adopted because of the real-time availability of the Nimrod data, and the short history and inconvenience of the Nimrod archive for re-running past cases. In practice, a reasonable variety of cloud and rainfall conditions was encountered over the two trial periods. From 29th March to 3rd April there was a slack, cold, mainly north to north-easterly airstream with a ridge dominating, but with enough instability for showers in some areas on most days. After 10th April, there was a much more mobile and unsettled period, with fronts crossing the country, and with post-frontal shower activity quite widespread at times.

During the trial, Latent Heat Nudging (LHN) was introduced operationally to the MES on 16th April, and therefore the verification scores are presented for the two time periods: pre- LHN and post-LHN. Any difference in the Nimrod version's relative performance during the two periods could be a consequence of the difference in the precipitation rate analysis, whereas any differences pre-LHN are due only to the cloud analysis changes. In practice, because of filtering present within the LHN algorithm, the impact of LHN was not expected to be very sensitive to the different degree of smoothing present in the input precipitation data.

3. Subjective assessment of precipitation forecasts

In the first 42 cases (*pre-LHN*) it was found that, overall, 19% of the cases using the Nimrod version produced rainfall fields which verified at least a little better than the operational charts and were therefore preferred. In 7% of the cases the current operational runs were preferred but in the majority (74%) there was no overall preference between the two runs.

In the 22 *post-LHN* runs, the Nimrod versions were preferred in 50% of the cases, the operational preferred in 14% and in the remainder (36%) there was no preference. In many of the cases where neither run was preferred over the other, there were no significant differences between the two runs.

The above findings imply that both the cloud analysis changes alone and the full package

(including the precipitation analysis change) lead to slightly improved precipitation forecasts overall. The most notable improvement found concerned a decaying front moving southeast across England and Wales in which the Nimrod version correctly kept a much more coherent band of rain than did the operational run (Figure 1). An example of a more minor improvement occurred in the t+18 forecast shown in Figure 2, where the Nimrod version correctly gave some indication of showers over East Anglia, which were absent in the operational forecast.

An example of a case in which the Nimrod version gave a poorer forecast can be seen in Figure 3. At t+6, the Nimrod version produced an area of rain from south Wales to the Wash, missing in the operational run, and for which there was scant evidence on the radar at that time. It was interesting to note, however, that 6 hours later at t+12, the radar showed an area of rain similar to that shown on the t+6 Nimrod frame. It could be said that the Nimrod run gave a correct signal for rainfall development, but with a significant timing error. Satellite imagery for this case did show extensive cirrus in the southern part of the model domain. It is known that mid-level instability can be triggered in the model spuriously (or too early) by the assimilation of MOPS cloud data in which thin cirrus has been incorrectly assigned to medium levels (Macpherson et al., 1996). The current method of avoiding this error is to disallow any extraction of cloud top information from the imagery if the background cloud field has any high cloud, indicating the possible presence of cirrus in the real atmosphere. For this case, the difference in background fields between the Nimrod and operational versions of MOPS may have led to different use of the imagery. In the near future, it is hoped to incorporate into Nimrod a scheme whereby cloud top temperature corrections will be applied to infrared data to improve the height assignment of semi-transparent cirrus. These will be obtained from simultaneous use of water vapour imagery.

Taking the 64 runs together, 30% of the Nimrod runs were preferred, 9% of the operational runs and the remaining 61% of runs had no significant differences or preference. Differences between the operational and trial forecasts typically disappeared after t+9 or t+12.

In the 19 runs where the Nimrod version produced the better or preferred result, the proportion of these (61%) in which convective rain was dominant was approximately the same as the proportion of all runs in which convective rain was the main source of precipitation, so little sensitivity to synoptic type seems to be evident in the Nimrod version's impact. In the purely convective situations in the early part of the trial, the Nimrod version appeared to do better more often than not by causing there to be *more* showers in the model output.

4. Objective verification

All the trial forecasts were run out to t+18. Objective verification of the trial forecasts and the first 18 hours of the operational forecasts was completed for a total of 55 forecasts (45 pre-LHN and 10 post-LHN). The results are averaged over a standard station list of mainly UK and Irish stations, with a few continental stations.

Figures 4 and 5 give the (pre-LHN) case-composite verification scores for total cloud cover and cloud base for cover>4.5 oktas, screen temperature, screen relative humidity and 10-metre wind.

Total cloud cover - Nimrod version reduces the negative bias slightly throughout the forecast and lowers the rms error up to t+9. The improvement at t+6 is just under 3%.

Cloud base - Nimrod version reduces the positive bias throughout the forecast, and lowers the rms error (by nearly 5% at t+9).

Temperature - Impact of Nimrod version very small - a 2% improvement in rms at t+3 and a 0.5% improvement overall.

Humidity - Nimrod version increases a positive bias by around 0.7% (in rh), which leads to an rms error larger by 2% (as a percentage of the operational error).

10-metre wind - Negligible impact.

A check on the possible impact of the precipitation analysis change was made by examining verification for the post-LHN period (Figure 6). For this smaller sample of forecasts, the same qualitative behaviour in the total cloud and rh biases is seen as in the larger pre-LHN sample. In terms of rms errors, the Nimrod cloud cover is still marginally better and the degradation in screen rh is less than for the pre-LHN period. It would be unjustified, though, to assume that the difference in relative impact is connected necessarily with the LHN change. The synoptic conditions may be more relevant, as the change in sign of cloud cover bias between Figure 4 and Figure 6 indicates.

A search was also made for a signal from the use of visible imagery, by verifying 00Z and 12Z forecasts separately (Figure 7). One might look for some extra benefit in the 12Z forecasts. In fact, the benefit from the Nimrod version is clearer in the 00Z sample, a finding for which we have no explanation. It is worth noting that the warm cloud top conditions likely to cause the 'infrared invisibility' problem did not occur during the trial.

References

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Nimrod **Operational** **Radar**

Nimrod **Operational** **Radar**

T+6 T+12

Nimrod **Operational** **Radar**

Figure 1: Nimrod and Operational t+6 forecasts valid at 00 UTC, 19th April 1996, with verifiying composite radar image.

Figure 3: Nimrod and Operational forecasts at t+6 and t+12 from data time 6 UTC, 20th April 1996, with verifiying composite radar images.

Figure 2: Nimrod and Operational t+18 forecasts valid at 12 UTC 2nd April 1996, with verifiying composite radar image.

Figure 4: Case-composite scores (from 45 pre-LHN cases) for Nimrod and Operational forecasts, for total cloud cover and cloud base with a threshold of >4.5 oktas.
Operational +- - - - - + Nimrod

Figure 5: Case-composite scores (from 45 pre-LHN cases) for Nimrod and Operational forecasts, for screen temperature, screen relative humidity and 10-metre wind.
Operational +- - - - - + Nimrod

Figure 6: Case-composite scores (from 10 post-LHN cases) for Nimrod and Operational forecasts, for total cloud cover and screen relative humidity.
Operational +- - - - - + Nimrod

Figure 7: Comparison of rms total cloud cover errors for 00Z and 12Z cases.
Operational +- - - - - + Nimrod